2007

Gravity Table Sorting of Commodity Corn

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ABSTRACT. *Gravity tables are used in the seed industry to sort seed corn and other seeds for upgrading seed quality. Tests were conducted to determine if commodity corn could be sorted for quality by gravity table. Three commodity corn lots were sorted using an Oliver model 50 gravity table. Samples were drawn at three times from the feed and from four discharge fractions: heavy, heavy/medium, medium, and light. All samples were tested for test weight, breakage susceptibility, moisture, Chowdhury damage, starch, protein, oil, and density. Three measurements of physical properties (test weight, breakage susceptibility, and Chowdhury damage) showed many significant differences among fractions at α = 0.05. Quality of the heavy fractions was highest, and decreased through the lighter fractions with the light fractions having the poorest quality. There were few differences among sampling times. Chemical properties (protein, oil, starch) and moisture showed little difference among fractions at α = 0.05. Removal of the light fraction from commodity corn lots can result in lower BCFM levels in this corn at final destinations, overseas or domestic.*

Keywords. *Corn, Gravity table, Breakage susceptibility.*

Corn is the leading grain export from the United States and in 2003-2004, the US exported about 50 million Mg of corn, out of 78 million Mg exported by all countries (USDA, 2005). Buyer satisfaction depends on maintaining quality and an increase in broken corn and foreign material during shipment constitutes a decrease in quality. Shipments arriving with a low level of broken corn and foreign material will have greater value for the end user.

BROKEN CORN AND FOREIGN MATERIAL (BCFM)

BCFM is defined as the percent weight of material that is removed from the corn by using a 4.76-mm (12/64-in.) round hole sieve, plus all non-corn material remaining on the sieve (USDA, 1996). Official USDA grades for corn limit BCFM to 2%, 3%, 4%, 5%, and 7% for grades 1, 2, 3, 4, and 5, respectively. BCFM is the most frequent cause of quality deterioration and grade loss during corn shipment (Bern and Hurburgh, 1992). Breakage-related complaints about U.S. corn became dominant in the 1960s as field shelling and high-temperature drying came into wide use (Hill, 2002).

BCFM is produced during corn handling operations and, therefore, increases during shipment. Paulsen and Hill (1977) tracked a shipment of corn from Toledo, Ohio, to Rotterdam, Holland. Samples taken as the ship was being loaded contained 3.4% BCFM, which meets the requirements for USDA Grade 3 corn. When the ship arrived in Rotterdam, samples contained 15.0% BCFM, which is too high to meet requirements for Grade 5. Another study looked at shipment of corn to be used for starch production in Japan (Paulsen et al., 1996). Corn arrived at wet milling plants containing 8% to 12% BCFM. Before starch is extracted from corn, BCFM is removed and sold at a loss for use as animal feed.

BREAKAGE SUSCEPTIBILITY

Breakage susceptibility is defined as the potential for kernels to fracture when subjected to impacts during handling and transport (AACC, 1983). It is quantified as the percent weight of BCFM in a sample after treatment in a breakage susceptibility tester. If combine settings are not correct for the crop conditions, the combine is likely to stress and crack the corn kernels. It has also been determined that if the corn is not harvested at moistures between 23% and 25%(all moistures are %-wet basis), stress crack formation and endosperm damage can increase by 33% (Zimmerman, 1968). Paulsen and Hummel (1981) stated that combines are a leading cause of stress cracks. A study performed by Pomeranz et al. (1986b) determined that drying corn at high temperatures caused it to become brittle and more susceptible to breakage. Another study by Thompson and Foster (1963) determined that high air temperatures during drying, followed by rapid cooling, caused significantly more stress cracks or damage to the corn than did unheated air. Gunasekaran and Paulsen (1985) found corn kernel breakage to be negatively correlated with kernel moisture. As kernel moisture goes down, breakage increases. As kernel moisture goes up to 25%, breakage decreases to near zero (Herum and Blaisdell, 1981).

BREAKAGE SUSCEPTIBILITY TESTERS

Testers have been developed to measure the tendency of corn to break during handling. One of these testers is the Stein Breakage Tester, a machine which subjects a sample of corn in a cup to repeated impacts from a motor-driven impeller.

Submitted for review in July 2005 as manuscript number FPE 5963; approved for publication by the Food & Process Engineering Institute Division of ASABE in November 2006.

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Kernels with few stress cracks are more likely to remain intact throughout the test. Another tester that has provided accurate and consistent results is the Wisconsin Breakage Tester (Watson and Herum, 1986). The Wisconsin Breakage Tester utilizes a centrifugal impeller which throws corn kernels against the steel sides of the tester using an impeller with four grooves.

Stein breakage tester results for samples taken during shipment of corn from Toledo, Ohio, to Rotterdam, Holland, showed that breakage susceptibility increased throughout the transport. Stein breakage susceptibility was 19% in Toledo and 25.5% in the barges at Rotterdam (Paulsen and Hill, 1977). Breakage susceptibility is important as a predictor of BCFM that will be developed during transport and handling. Low breakage susceptibility means minimal BCFM creation during handling and transporting of corn.

Paulsen and Hill (1983) tested samples of corn from nine ocean vessels carrying corn from the United States to England. Their data show that Stein breakage results (4-min test, 5.95-mm sieve) at the time of loading are related to the percentage points increase in BCFM between origin and destination, with $R^2 = 0.44$ (fig. 1).

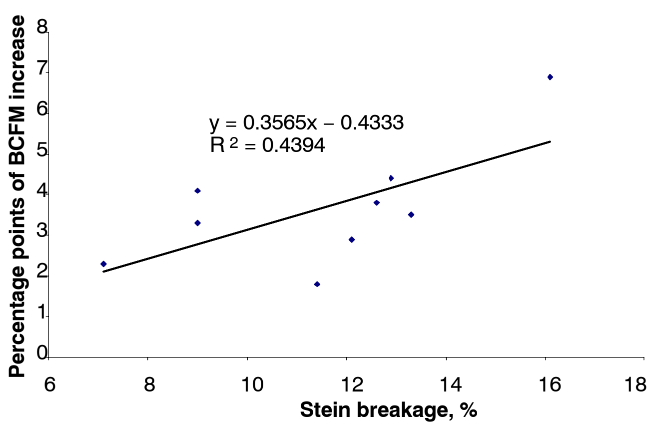

Figure 1. Relationship of BCFM increase during shipment and 4-min Stein breakage prior to loading for nine shiploads of corn shipped to England (Paulsen and Hill, 1983).

Gravity Tables

Gravity tables (fig. 2) are used in the seed industry and in other industries to sort material by physical properties including bulk density and particle size. Gravity separation is achieved by two simultaneous processes, which employ fans and vibration. Within the gravity table, fans create pressure under a porous membrane (deck) that supports the material. This pressure gradually lifts the lighter seeds and causes a reduced amount of frictional force between the seeds and the deck or other seeds. The second process, vibration, causes the seeds touching the deck to move up the sloping deck. The deck has two slopes, a side slope from high side to low side and an end slope from the feed end down to the discharge end of the gravity table. As the deck vibrates, heavier seeds that are touching the deck slowly move up the slope to the higher end of the discharge. The lighter seeds that are not touching the deck begin to migrate slowly down the slope due to gravity. This action allows the sorting of material based on properties that affect movements of seeds on the gravity table.

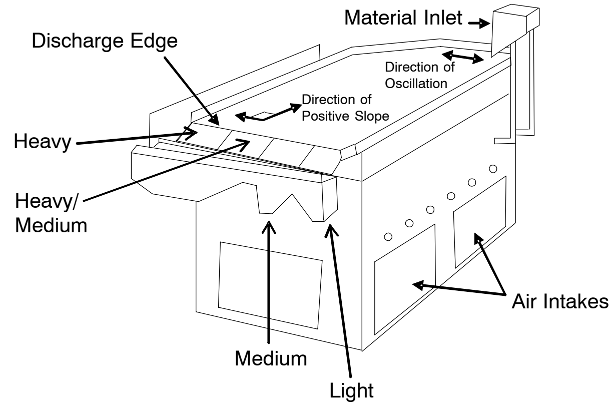

Figure 2. Gravity table operation and sampling locations.

Gaul et al. (1986) determined that airflow is the most important factor in sorting grain. When air is used alone, the lighter material rises. However, when vibration is used alone, the heavier material rises. Appropriate air and vibration adjustments can result in the best possible separations.

Risse et al. (1991a) performed a study involving removal of shriveled soybean seeds from a lot containing a mixture of shriveled and non-shriveled soybeans. A system of an aspirator, spiral separator, and a gravity table was used for the conditioning process. While the aspirator removed 50% of the shriveled soybean seeds, the spiral separator and gravity table were still needed to achieve high quality seed. Risse et al. (1991b) determined that gravity separation could increase quality factors including test weight, volume of 100 kernels, weight of 100 kernels, and kernel density by removing the lighter, smaller, and poorer quality seeds and other materials.

Commodity Corn

Although there have been several studies involving use of gravity tables for soybean and corn seeds, no reports of studies involving commercial market corn were found in the literature. The use of a gravity table on commodity corn may provide a way to reduce BCFM formation during overseas shipment by sorting out corn likely to break. Equipment costs for achieving necessary flow rates may limit applications for low-value grain.

Objective

The objective of this study was to determine if commodity corn could be sorted by breakage susceptibility and other quality factors such as size, shape, and density using a gravity table.

Materials and Methods

Three lots of corn were cleaned and sorted by use of a gravity table. Samples drawn during this process were tested for test weight, moisture, breakage susceptibility, mechanical damage, and constituent values.

Test Corn

Three lots of 2000-season commodity corn were tested (table 1). Lot 1 consisted of 432 kg of commodity corn purchased at the West Central Coop Boone Elevator in May 2001. Lot 2 was 381 kg of Wilson 1664 hybrid purchased from Wilson Seeds Inc. of Harlan, Iowa, in June 2001. Lot 3

Table 1. Test corn information.

		Lot 1	Lot 2	Lot 3
	Hybrid	Not Defined	Commodity Hybrid A	Commodity Hybrid B
BCFM	Quantity (kg)	432	381	454
	Scalping (%)	1.3	0.53	0.33
	Fines (%)	1.1	0.28	0.07

was 454 kg of Pioneer 3335 purchased from Pioneer Hybrid, Lynnville, Iowa, in July 2001. Lot 2 was dried using heated air. The drying histories of lots 1 and 3 are unknown. Prior to testing, all lots were stored up to two weeks in storage bins in the Iowa State University Seed Science Center. A Crippen air cleaner Model H-434-A (Crippen Manufacturing Co., St. Louis, Mich.) was used to clean corn lots prior to testing. This machine uses a 10.3-mm (26/64-in.) scalping screen and a 4.76-mm (12/64-in.) screen to remove fine material.

Oliver Gravity Table

An Oliver Gravity Table Model 50 (Oliver Manufacturing Co., Rocky Ford, Colo.), with a corn capacity of 1600 kg/h (63 bu/h), was used to sort the corn lots. It was adjusted for 75% of maximum airflow at the intake end of the deck, 50% of maximum airflow in the middle of the deck, and 25% of maximum flow at the discharge end of the deck. The vibrator eccentric was set at 480 rpm. These adjustments were made by an experienced operator in order to optimize operation. Gravity table discharge layout is specified in table 2. Each corn lot took about 10 min to sort.

Sampling

Corn was separated into heavy, heavy/medium, medium, and light fractions by the gravity separator (fig. 2). The percent of total corn flow routed to each of these fraction categories was varied among lots. Samples were drawn at three times during each run from the four locations as well as from the feed. The first set of samples was drawn as soon as the gravity table was adjusted properly and the corn was separating effectively on the deck. The second set of samples was drawn 5 min into the experiment. The third set of samples was drawn near the end of the process.

Table 2. Gravity table deck layout.

	Lots One and Two	
Fraction	Length (cm)	Total Length (%)
Heavy	362	52.8
Heavy-medium	178	25.9
Medium	121	17.6
Light	25.4	3.7
Total	686.4	100

	Lot Three	
Fraction	Length (cm)	Total Length (%)
Heavy	534	77.8
Heavy/Medium	50.8	7.4
Medium	50.8	7.4
Light	50.8	7.4
Total	686.4	100

Test Weight and Moisture

Test weight and moisture content were determined using a Dickey-john GAC 2000 Grain Analysis Computer (Dickey-john Corp., Auburn, Ill.). Moisture content was also determined using the 103°C, 72-h hot-air oven procedure (*ASAE Standards*, 2001), and by a near infrared instrument (see infrared analysis).

Breakage

Triplicate breakage tests were conducted on subsamples cut from all samples using both a Stein CK-2M breakage tester (Fred Stein Laboratories Inc, Atchison, Kan.) and a Wisconsin breakage tester (no longer being manufactured). The Stein test was 4 min using 100-g samples. The Wisconsin test used 250-g samples. A 4.76-mm (12/64-in.) round hole sieve was used with both testers.

Chowdhury Damage

The Chowdhury Damage Test (Chowdhury and Buchele, 1976) was performed on all samples. Corn samples were cleaned using a 6.34-mm (16/64-in.) round hole sieve and 100-g sub-samples of corn were obtained by using a Boerner divider. Sub-samples were then placed in 5 mL of a fast green dye solution and 95 mL of distilled water for 30 s. Immediately after staining, the corn was transferred into a strainer and rinsed under tap water for 30 s. The strainer and corn were placed in an extracting solution consisting of 5 mL of extracting concentrate in 245 mL of distilled water. After 30 s of continuous stirring, the corn was removed from the extracting solution. A portion of the extraction solution was then placed in a vial, which was inserted into the Digital Grain Quality tester. This tester then displays a number between 1 and 100, which quantifies corn damage.

Near Infrared Analysis

An InfraTec 1229 (InfraTec GmbH, Dresden, Germany) grain analyzer in the Iowa State University Grain Quality Lab was used for near infrared transmittance tests for moisture, protein, oil, starch, and density on all samples.

Statistical Analysis

Statistical analysis was carried out using Statistical Analysis System (SAS) software. Regression analysis was performed on data for figures 1, 3, and 4.

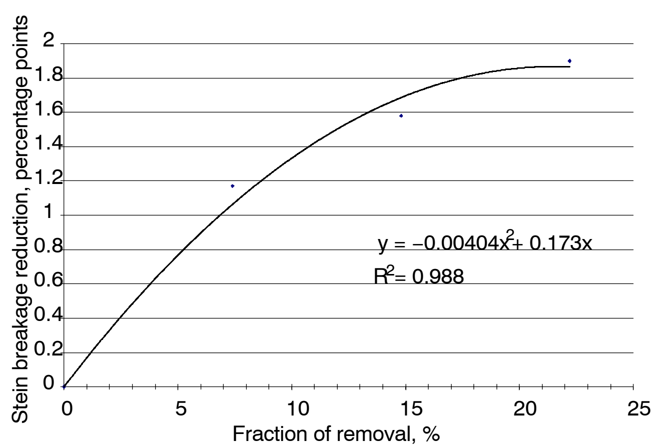

Figure 3. Effect of removing light fraction on the Stein breakage of the remainder for Lot 3.

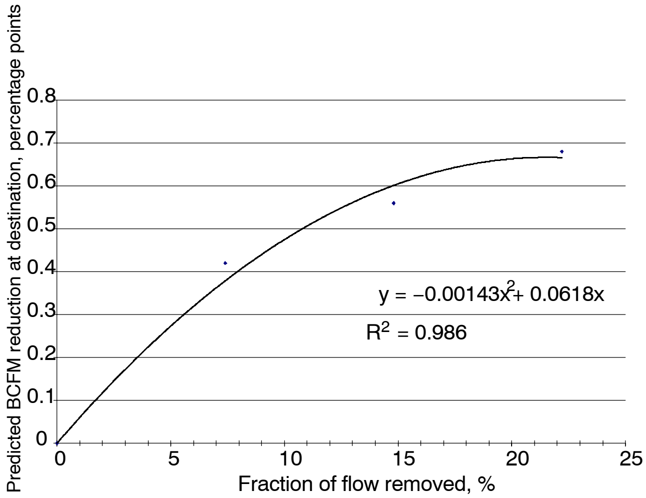

Figure 4. Predicted reduction in BCFM when light fraction of Lot 3 is removed.

Results and Discussion

Results are shown in tables 3, 4, and 5. Tabled means are the average of three determinations. Statistical analysis values are found in table 6.

Test Weight

Test weight means are shown in line two of tables 3, 4, 5, for lots 1, 2, 3, respectively. The gravity table separated corn into fractions with test weights having ranges of 4 to 6 lb/bu for the three lots. In every lot, the greatest test weight difference occurred between the light and medium lots. For lots 1 and 2, all test weight means were significantly different. For lot 3, with its different gravity table layout, the inner two fractions (heavy-medium and medium) were not significantly different.

Breakage

Stein and Wisconsin breakage means are shown on lines three and four of table 3, 4, and 5, respectively. Gravity table treatment proved capable of separating the corn lots according to breakage susceptibility. Results show that separation according to Stein breakage is more effective than separation by Wisconsin breakage. For lot 1 (table 3), Stein means for all four fractions were significantly different. Stein breakage of the light fraction was almost six times that of the heavy fraction, and more than two times that of the medium fraction. In lots 2 and 3 (tables 4 and 5), Stein means of two adjacent fractions were not significantly different. Wisconsin breakage means exhibited fewer differences. The greatest ranges occurred in lots 2 and 3 where the Wisconsin breakage of the light fraction was about 150% of that of the heavy value. Lot 3 had two significantly different fractions, while lots 1 and 2 had one each. Possibly the Stein results exhibit more differences because the instrument stresses kernels more through thousands of impacts. The Wisconsin tester throws each kernel only once.

Table 3. Test means[a] (standard deviations) for Lot 1.

	Feed	Heavy	Heavy/Medium	Medium	Light
Fraction of flow (%)	100	52.8	25.9	17.6	3.7
Test weight (lb/bu)	57.72 0.35 b (0.35)	58.33 0.25 a (0.25)	56.59 0.33 c (0.33)	55.02 0.42 d (0.42)	52.71 0.41 e (0.41)
Stein breakage (%)	3.41 0.60 cd (0.60)	2.45 0.48 d (0.48)	3.92 0.89 c (0.89)	5.56 1.08 b (1.08)	13.77 1.68 a (1.68)
Wisconsin breakage (%)	9.46 0.49 b (0.49)	9.04 0.39 b (0.39)	8.65 0.71 b (0.71)	9.34 0.50 b (0.50)	13.20 0.77 a (0.77)
Chowdhury damage	9.56 2.01 cd (2.01)	8.11 0.93 c (0.93)	10.11 1.27 c (1.27)	12.44 1.42 b (1.42)	19.44 2.92 a (2.92)
Oven moisture (%)	13.46 0.41 a (0.41)	13.47 0.43 a (0.43)	13.46 0.47 a (0.47)	13.77 0.54 a (0.54)	13.81 0.37 a (0.37)
GAC 2000 moisture (%)	13.66 0.11 a (0.11)	13.61 0.13 ab (0.13)	13.51 0.16 ab (0.16)	13.46 0.15 b (0.15)	13.09 0.11 c (0.11)
NIR moisture (%)	13.81 0.09 a (0.09)	13.69 0.16 a (0.16)	13.80 0.13 a (0.13)	13.81 0.11 a (0.11)	13.67 0.11 a (0.11)
NIR protein (%)	7.87 0.18 b (0.18)	7.77 0.18 b (0.18)	7.91 0.08 b (0.08)	7.92 0.19 b (0.19)	8.22 0.18 a (0.18)
NIR oil (%)	3.61 0.11 a (0.11)	3.62 0.11 a (0.11)	3.67 0.10 a (0.10)	3.63 0.18 a (0.18)	3.71 0.17 a (0.17)
NIR starch (%)	61.32 0.20 ab (0.20)	61.56 0.34 a (0.34)	61.37 0.31 ab (0.31)	61.11 0.21 bc (0.21)	60.91 0.39 c (0.39)
NIR density	1.27 0.01 b (0.01)	1.27 0.01 a (0.01)	1.26 0.01 b (0.01)	1.25 0.01 c (0.01)	1.24 0.01 d (0.01)

[a] Numbers in a row with the same letter are not significantly different at $P < 0.05$.

Table 4. Test means[a] (standard deviations) for Lot 2.

	Feed	Heavy	Heavy/Medium	Medium	Light
Fraction of flow (%)	100	52.8	25.9	17.6	3.7
Test weight (lb/bu)	58.00 0.32 b (0.32)	58.87 0.31 a (0.31)	57.31 0.35 c (0.35)	56.33 0.31 d (0.31)	53.38 0.62 e (0.62)
Stein breakage (%)	2.33 0.41 c (0.41)	1.55 0.25 c (0.25)	2.18 0.46 c (0.46)	4.96 0.90 b (0.90)	14.17 0.90 a (0.90)
Wisconsin breakage (%)	7.69 0.56 b (0.56)	7.67 0.33 b (0.33)	7.36 0.62 b (0.62)	7.95 0.63 b (0.63)	11.84 0.66 a (0.66)
Chowdhury damage	8.22 1.56 bc (1.56)	6.67 0.87 c (0.87)	8.00 1.00 bc (1.00)	9.56 1.33 b (1.33)	16.78 1.39 a (1.39)
Oven moisture (%)	12.98 0.34 a (0.34)	12.86 0.33 a (0.33)	13.14 0.57 a (0.57)	13.11 0.52 a (0.52)	13.03 0.38 a (0.38)
GAC 2000 moisture (%)	13.22 0.15 a (0.15)	13.14 0.10 a (0.10)	13.17 0.14 a (0.14)	13.08 0.12 a (0.12)	12.61 0.12 b (0.12)
NIR moisture (%)	13.44 0.14 a (0.14)	13.48 0.07 a (0.07)	13.51 0.09 a (0.09)	13.48 0.08 a (0.08)	13.41 0.08 a (0.08)
NIR protein (%)	7.87 0.12 a (0.12)	7.70 0.21 a (0.21)	7.79 0.21 a (0.21)	7.81 0.13 a (0.13)	7.94 0.20 a (0.20)
NIR oil (%)	3.56 0.13 a (0.13)	3.51 0.13 a (0.13)	3.57 0.15 a (0.15)	3.60 0.11 a (0.11)	3.68 0.11 a (0.11)
NIR starch (%)	61.59 0.33 ab (0.33)	61.64 0.24 a (0.24)	61.49 0.15 ab (0.15)	61.36 0.14 b (0.14)	61.33 0.14 b (0.14)
NIR density	1.27 0.01 a (0.01)	1.27 0.01 a (0.01)	1.25 0.00 b (0.00)	1.25 0.01 bc (0.01)	1.24 0.01 c (0.01)

[a] Numbers in a row with the same letter are not significantly different at $P < 0.05$.

Table 5. Test means[a] (standard deviations) for Lot 3.

	Feed	Heavy	Medium	Medium/Light	Light
Fraction of flow (%)	100	77.8	7.4	7.4	7.4
Test weight (lb/bu)	59.45 0.15 b (0.15)	60.13 0.54 a (0.54)	58.76 0.25 c (0.25)	58.33 0.30 c (0.30)	56.35 0.30 d (0.30)
Stein breakage (%)	9.90 1.30 cd (1.30)	8.04 1.48 d (1.48)	11.66 0.63 bc (0.63)	13.43 1.92 b (1.92)	20.65 1.64 a (1.64)
Wisconsin breakage (%)	15.47 0.76 bc (0.76)	15.15 0.80 c (0.80)	15.77 0.58 bc (0.58)	16.29 0.43 b (0.43)	19.14 0.93 a (0.93)
Chowdhury damage	7.25 0.67 bc (0.67)	5.67 0.67 d (0.67)	7.08 0.71 c (0.71)	8.17 0.71 b (0.71)	15.00 1.00 a (1.00)
Oven moisture (%)	12.78 0.22 a (0.22)	12.82 0.24 a (0.24)	12.79 0.25 a (0.25)	12.81 0.29 a (0.29)	12.88 0.32 a (0.32)
GAC 2000 moisture (%)	13.16 0.11 b (0.11)	13.29 0.09 a (0.09)	13.13 0.07 b (0.07)	13.05 0.09 b (0.09)	12.80 0.10 c (0.10)
NIR moisture (%)	13.51 0.17 a (0.17)	13.33 0.10 b (0.10)	13.42 0.16 ab (0.16)	13.48 0.22 ab (0.22)	13.51 0.16 a (0.16)
NIR protein (%)	8.22 0.21 a (0.21)	8.30 0.23 a (0.23)	8.15 0.22 a (0.22)	8.21 0.14 a (0.14)	8.29 0.18 a (0.18)
NIR oil (%)	3.53 0.13 ab (0.13)	3.53 0.15 ab (0.15)	3.44 0.14 b (0.14)	3.53 0.12 ab (0.12)	3.66 0.16 a (0.16)
NIR starch (%)	61.53 0.29 a (0.29)	61.69 0.26 a (0.26)	61.59 0.32 a (0.32)	61.41 0.29 ab (0.29)	61.15 0.32 b (0.32)
NIR density	1.26 0.00 b (0.00)	1.27 0.01 a (0.01)	1.25 0.01 b (0.01)	1.25 0.01 c (0.01)	1.24 0.01 d (0.01)

[a] Numbers in a row with the same letter are not significantly different at $P < 0.05$.

Chowdhury Damage.

Chowdhury Damage means are shown on line five of tables 3, 4, and 5 for lots 1, 2, and 3, respectively. Chowdhury Damage values are responsive to the area of dye-absorbing starch exposed on kernels due to kernel damage. The Chowdhury Damage values of the light fractions were about 2.5 times those of the heavy fractions. Corn lots 1 and 2 each had one or two significantly different Chowdhury Damage means. For lot 3, with its dividers shifted toward the light end, all four means were significantly different. Because the Chowdhury Damage values indicate kernel damage which has exposed starch, it is likely that storability will be poorer for the lighter, more damaged fractions.

Moisture Contents

Oven, GAC 2000, and NIR moistures are found on lines 6, 7, and 8 of tables 3, 4, and 5, respectively. There were no significant differences between any oven moisture means. This suggests that corn fractions having different bulk densities within the same lot do not have different equilibrium moisture contents. GAC 2000 moisture means averaged 0.2 to 0.4 points higher than oven moisture means. All GAC 2000 light means from all three lots were significantly lower than medium means. Lots 1 and 3 exhibited a few other significant differences as well. Since oven means show no differences among fractions, differences in these GAC 2000 moisture means are probably due to bulk density effects, which affect electronic moisture meters using the capacitive principle. Grain at low bulk density tends to read low in moisture, compared to oven values.

NIR Protein

The NIR protein values are shown in line nine of tables 3, 4, 5, for, lots 1, 2, 3, respectively. In lot 1, the NIR protein values range from 7.8% to 8.2%. In this fraction, the feed, heavy, heavy medium, and medium fractions were not significantly different. The light fraction was significantly different from the other fractions. It was determined that for lots 2 and 3, no fraction was significantly different from any other fraction within the respective lot.

NIR Oil

The NIR oil values are shown in line 10 of tables 3, 4, 5, for lots 1, 2, 3, respectively. For lots 1 and 2, there were no significant differences among fractions. In lot 3, the range was 0.3 percentage points and oil content for the light fraction was the highest. In one instance the difference between fractions was significant. For lots 1 and 3, NIR oil values showed significant differences among sampling times. No explanation for this is known by the authors.

NIR Starch

The NIR starch values are shown in line 11 of tables 3, 4, 5, for lots 1, 2, 3, respectively. There was little variation in

Table 6. Statistical analysis results for different lots, sampling points and sampling times.

	Lot 1		Lot 2		Lot 3	
	Sampling Point	SamplingTime	Sampling Point	SamplingTime	Sampling Point	SamplingTime
Test weight	0.0001	0.0207	0.0001	0.0001	0.0001	0.0438
Stein breakage	0.0001	0.5893[a]	0.0001	0.7747[a]	0.0001	0.0752[a]
Wisconsin breakage	0.0001	0.5482[a]	0.0001	0.7545[a]	0.0001	0.6872[a]
Chowdhury damage	0.0001	0.2427[a]	0.0001	0.195[a]	0.0001	0.4683[a]
Oven moisture	0.3572[a]	0.7209[a]	0.7453[a]	0.6731[a]	0.9362[a]	0.9999[a]
GAC 2000 moisture	0.0001	0.0470	0.0001	0.3766[a]	0.0001	0.3208[a]
NIR moisture	0.0168	0.2986[a]	0.1508[a]	0.1624[a]	0.0160	0.0499
NIR protein	0.0001	0.1453[a]	0.1048[a]	0.4281[a]	0.2791[a]	0.8437[a]
NIR oil	0.4417[a]	0.0285	0.127[a]	0.8203[a]	0.0037	0.0078
NIR starch	0.0004	0.0153	0.0122	0.06[a]	0.0009	0.0695[a]
NIR density	0.0001	0.1615[a]	0.0001	0.5937[a]	0.0001	0.2308[a]

[a] Numbers in a row greater than 0.05 indicate the sampling point or time is not significantly different.

starch among the gravity table output fractions. The range of starch values for lots 1, 2, and 3 were only 0.7, 0.3, and 0.5 percentage points, respectively. In all cases, starch decreases across the fractions from heavy to light. In several instances, differences among fractions, though low, are statistically significant.

NIR Kernel Density

Kernel density tended to decrease slightly across fractions from heavy to light. The range was 0.1g/cm^3 in all three lots. Though the differences among means were small, in several instances they were statistically significant. In lots 1 and 3, every mean was significantly different from the others.

Sampling Points and Sampling Times

Table 6 shows statistical analysis results for sampling points and sampling times. Among all parameters measured, only test weight showed significant differences among sampling times for all three lots. Possibly some segregation of kernels by kernel density, surface texture, or size occurred during prior handling of the three lots.

Discussion

In general, quality, as measured by bulk density, breakage susceptibility and kernel damage goes down as one looks at fractions from heavy to light. Fractions are likely sorted on the basis of properties such as kernel shape, size, and surface texture. All fractions are at about the same moisture and kernel density, and contain about the same percentages of protein, oil, and starch. Therefore, if a light fraction is removed from a corn lot, the remaining corn would have a lower tendency to increase in BCFM during shipment, and a better storability, compared to the original lot. But both remaining fractions would be essentially the same in moisture and nutritional properties.

Effects of Removing a Light Fraction

Figure 3 shows the predicted Stein breakage levels, assuming various percentages of the lighter corn fraction are removed. The graph predicts that Stein breakage of the heavy fraction will be reduced by nearly two percentage points if 23% of the lighter fraction is removed. The figure 1 model predicts that BCFM increase during overseas shipment will be reduced by 0.36 percentage points per percentage point of Stein breakage reduction prior to -shipment. Figure 4 shows the predicted BCFM reduction at an overseas destination when various percentages of light fraction are removed from Lot 3. When 23% of the lighter fraction is removed, a reduction of nearly 0.7 percentage points of BCFM is predicted. Although a BCFM reduction is predicted as a result of gravity table sorting of commodity corn, equipment costs for achieving necessary flow rates may limit applicability for this low-value product.

Suggestions for Future Research

Additional testing will better define the capability of gravity separators to sort commodity corn for quality. Larger and different brands of machines should be tested, and corn at different moistures and from different crop years should be used. Effects of various gravity table adjustments need to be determined so that settings optimize the machine's capability for this sorting task. An engineering economic analysis is needed to determine when this sorting is cost effective. Respirometer tests can determine if corn storability is different among the fractions.

Conclusions

Results from gravity table sorting of three lots of dry commodity corn lead to these conclusions:

- The gravity table can effectively sort corn into fractions according to test weight, breakage susceptibility, and mechanical damage. Physical properties involved are likely kernel size, shape, and surface texture.
- Sorted corn fractions vary little in moisture, protein, oil, starch, and kernel density.
- Gravity table sorting has the potential to reduce the BCFM increase occurring as corn is shipped overseas.

Acknowledgment

The authors are grateful to Glenn Rippke and the Iowa State University Grain Quality Laboratory for assistance with NIR analysis.

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